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MISCELLANEOUS PAPER C-78-16

TESTS OF BRICK-VENEER WALLS AND CLOSURES FOR RESISTANCE TO FLOODWATERS

by

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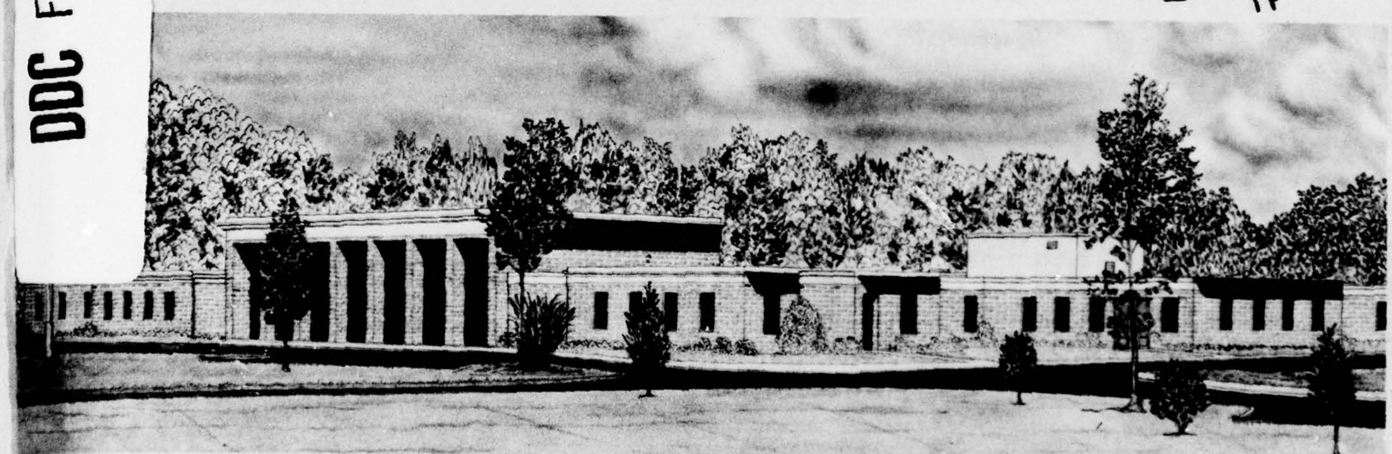
December 1978
Final Report



Prepared for U. S. Army Engineer Division, Lower Mississippi Valley
P. O. Box 80, Vicksburg, Miss. 39180

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Flood damage	Walls

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Floodwaters are a problem and expense to the owners of many homes and commercial buildings. It is important to determine expedient, feasible, and effective ways of floodproofing buildings which are subject to potential flooding. This study is limited to the common brick-veneer wall. Cont

Important conclusions which were reached while performing this study are:

(Continued)

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20. ABSTRACT (Continued).

a. The common brick-veneer wall leaks excessively.

b. The permeability of the wall to water can only be significantly reduced by using a coating which is thick or has body. This type of coating must be applied with great care or leaks in the walls will still exist. This solution was not successfully tested in the laboratory experiments. Because of excessive coating material, time, and care this may not offer a practical solution.

c. For a closure to be watertight, it must have gasket material at its connection to the side walls and bottom and must be bolted in place. The connecting members between the closure and the side walls and floor must be continuous and sealed securely.

d. Water will flow freely through the first layer of a two-layer brick wall and along a water barrier in the wall.

e. A two-layer brick wall will support greater water depths than a one-layer brick wall.

f. A tubular seal and plastic sheet can be used to eliminate water flow through a wall and closure.

CONT

The limited tests run show that there are answers to the floodproofing problem and that effective procedures can be established which will allow brick-veneer walls to structurally support any reasonable water depth.

It is not advisable to develop a system for reducing flow of water through walls and depend on it without first testing it for performance.

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PREFACE

The experimental investigation of brick-veneer walls and closures for their resistance to floodwaters was performed for the U.S. Army Corps of Engineers, Lower Mississippi Valley Division (LMVD), by the Concrete Laboratory (CL), U. S. Army Engineer Waterways Experiment Station (WES), in accordance with authority provided in DA Form 2544, dated 24 April 1978, to complete documentation of laboratory tests made for flood-resistant research for brick-veneer residential structures. This is the second report in this investigation. The first report was prepared by C. E. Pace and R. L. Campbell and published in May 1978 as WES Technical Report C-78-3, "Structural Integrity of Brick-Veneer Buildings."

The project was monitored by Mr. Lawrence Flanagan of LMVD. Mr. Flanagan worked very closely with the project and was very helpful in planning and conducting the study. His help and knowledge in the field were greatly appreciated.

The study was performed under the direction of Messrs. Bryant Mather, J. M. Scanlon, and J. E. McDonald, CL. The instrumentation work was performed by Mr. Dale Glass. Editing of the report by Mrs. Kathryn Stept is appreciated. The tests were conducted by Dr. C. E. Pace and Mr. Robert Denson. The report was prepared by Dr. C. E. Pace.

The Commander and Director of WES during the conduct of this test program and the preparation and publication of this report was COL John L. Cannon, CE. Mr. F. R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	0.0254	metres
feet	0.3048	metres
pounds (mass)	0.4539924	kilograms
pounds (force)	4.448222	newtons
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (force) per square inch	6.894757	kilopascals
tons (force) per square foot	95.76052	kilopascals
feet per second	0.3048	metres per second

TESTS ON BRICK-VENEER WALLS AND CLOSURES FOR RESISTANCE TO FLOODWATERS

PART I: INTRODUCTION

1. Floodwaters are a problem and expense to the owners of many residential and commercial buildings. Homeowners whose homes are subject to intermediate flooding should have good guidance for floodproofing because of hardship and expense to them and to the Government. Since brick-veneer is a very common home construction method, the experimental tests and this report deal with the treatment of brick-veneer walls and closures to reduce the flow of water through them.

2. Besides brick-veneer buildings being structurally capable of withstanding potential flood loads, there should be expedient, feasible, and effective ways of floodproofing the brick-veneer wall, eliminating underseepage and preventing excessive flow of water through closures, such as doors and windows. The problem of underseepage is not treated in this report. A discussion of structural integrity of brick-veneer buildings was given in a previous report.*

3. Water is very difficult to contain; therefore, it is not advisable to develop a system for reducing the flow of water through a barrier and depend on it to work without first testing it for adequate performance.

4. There are many materials and techniques for reducing the flow of water through brick-veneer walls and closures; therefore, the most promising of these should be tested for adequacy. The most desirable means of testing brick-veneer walls, to use actual houses, would be too expensive. Even if one could test a house of brick-veneer construction (which would still be very expensive), there are many variations in foundation materials and house construction; therefore, the tests would be significant for only a particular foundation and a particular set of construction variables.

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*Pace, C. E. and Campbell, R. L., "Structural Integrity of Brick-Veneer Buildings," Technical Report C-78-3, May 1978; U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

5. Even though it is the most desirable, it is not necessary to test an actual house to determine if certain materials and closure systems will adequately reduce the leakage of water. The tests in this study were performed on walls and closures in a laboratory environment.

PART II: EXPERIMENTAL TEST PLANS

6. For laboratory testing, it is best to have the test walls as simple as possible, but adequate for evaluating the penetration of water through the walls and the closures:

7. The test plans are as follows:

   a. Five sets of short walls were constructed (Figure 1).

   b. A standard door space was left between each pair of walls for the placement of closures.

   c. A restraining frame (Figure 2) was installed in the door opening from whose sides the closure could be pulled by springs (Figure 3) to seal it against the brick as could be done on an ordinary house.

   d. A bulkhead constructed of plywood and 2 x 4's (Figures 4 and 5) was placed across the walls and closures and sealed to the floor and to the walls' outer edges to contain the water. Different wall coatings and closure constructions were tested with this system.

   e. Since prototype wall tests had already been performed and the deflected wall shape for various water depths measured, it was decided to use a jacking and gaging system (Figures 6, 7, and 8) to make the walls have representative deflections for various water depths. After the tests had started, it was decided that the jacking system was not necessary.

   f. The deflected shape of the wall was measured as the water depth was increased.

8. The bulkhead was sealed to the ends of the brick wall and floor for various tests by means of rubber gasket material and one of the following compounds.

   a. Latex caulking.

   b. Weatherstrip adhesive.

If the latex caulking was not allowed to dry, it had a tendency to become soluble. Even when the caulking was allowed to dry, the weatherstripping compound created the best seal.

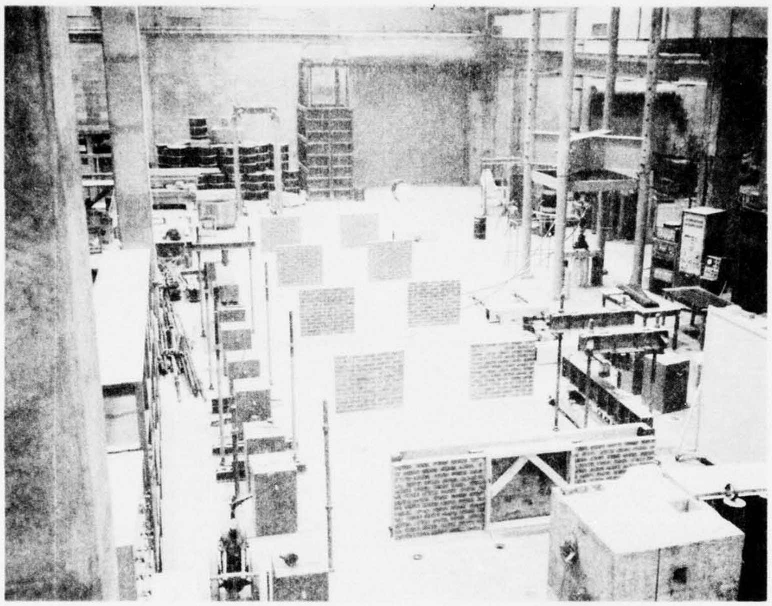

Figure 1. Five sets of short walls

Figure 2. A restraining frame placed between the brick walls from which the closure can be pulled against the walls by springs

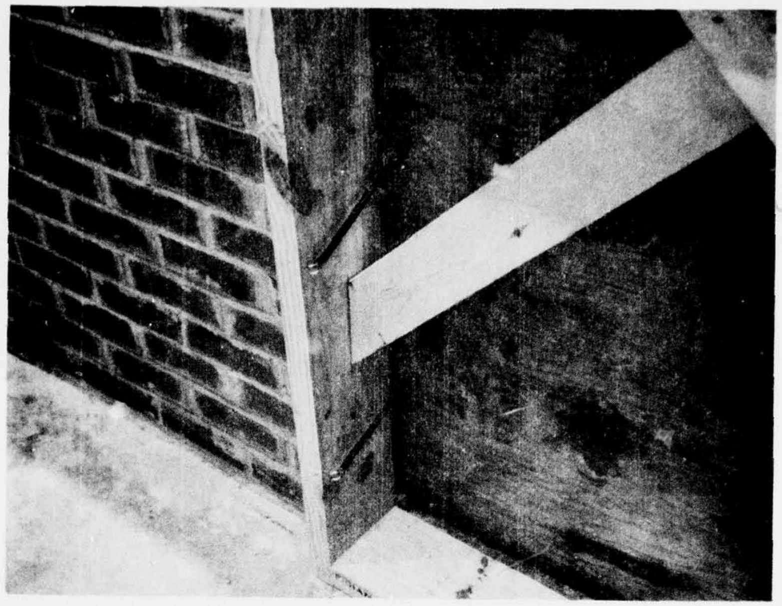

Figure 3. Springs used to pull the closure against the wall and down to the floor

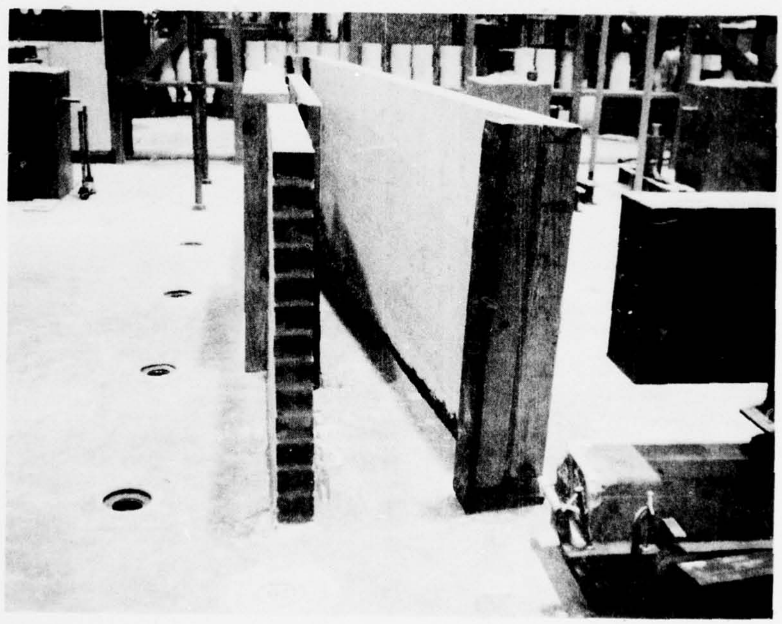

Figure 4. View 1 - bulkhead to contain water against the wall and closure

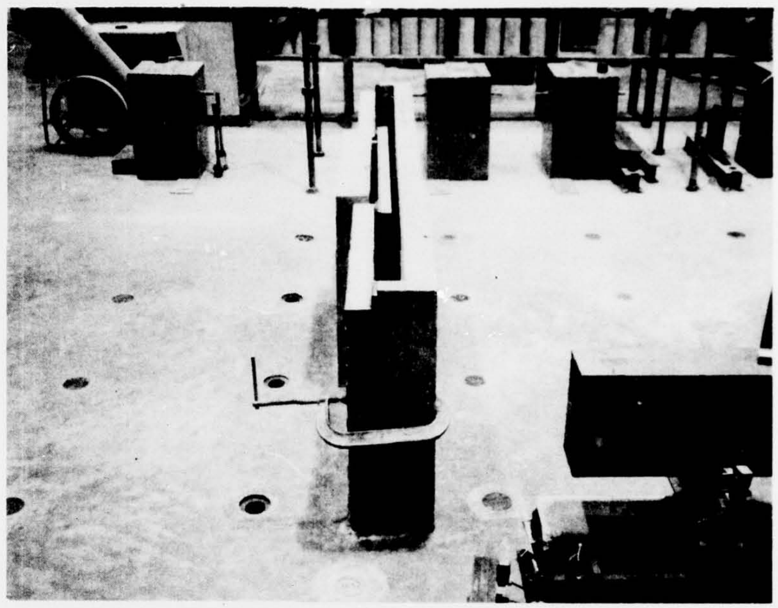

Figure 5. View 2 - bulkhead to contain water against the wall and closure

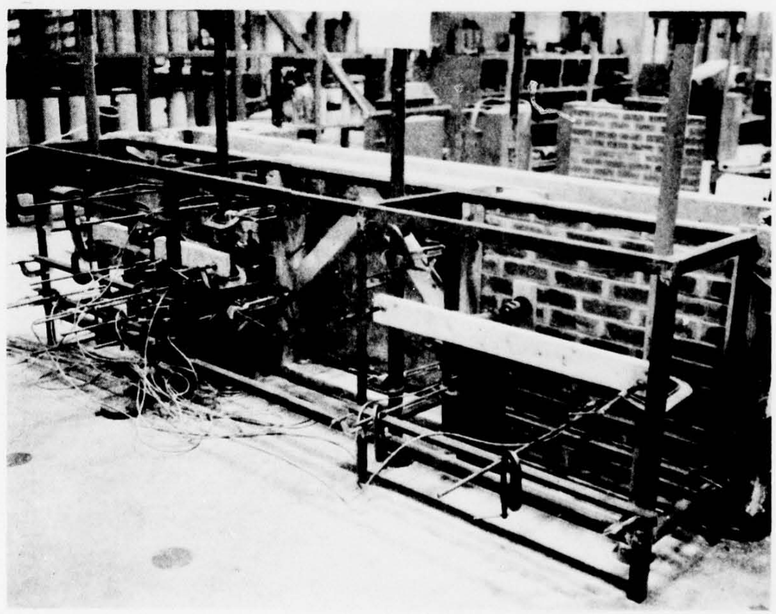

Figure 6. Jacking and gaging system

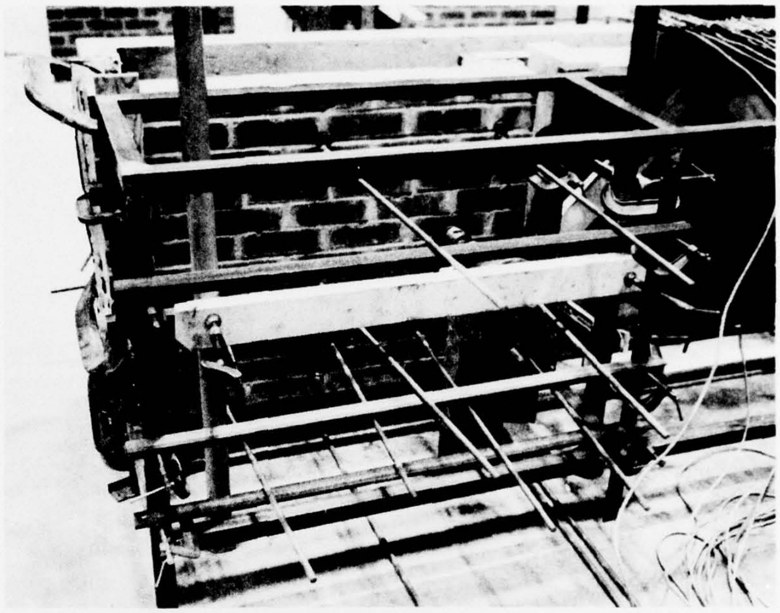

Figure 7. Jacking and gage support system

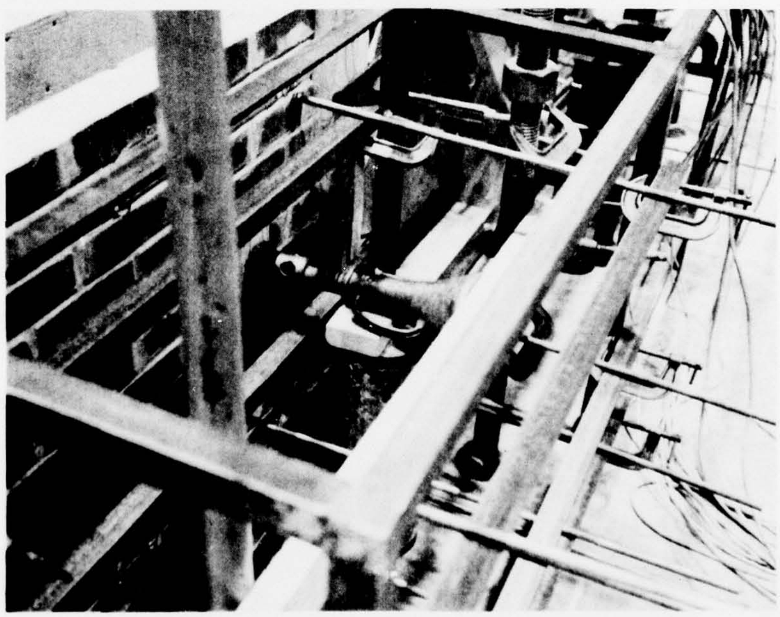

Figure 8. Jacking system

PART III: CLOSURES, TESTS, AND TEST RESULTS

Wall 1

9. The summary of tests on Wall 1 is contained in the following tabulation.

Test	Closure	Wall	Test Results
1	A closure constructed of plywood and 2 x 2's (Figure 9) was used. Rubber gasket material and caulking compound were used to seal the closure to the brick wall and floor. This closure was considered to be one that an ordinary homeowner could construct and use economically.	Nothing was put on the brick-veneer wall.	The wall leaked so badly that the closure could not be tested. It took seven tubes of caulking to seal the closure to the brick wall and floor. For several openings this would be an unreasonable amount of sealing compound.
2	The same as for Test 1.	Two commercially available coatings were used. One was used on one-half of the wall and the other on the other half of the wall. The coatings were about the consistency of water. The wall was soaked with the coatings.	The wall leaked so badly that the closure could not be tested. Any coating which will adequately reduce flow through the wall must be thick or have body. The low-viscosity coatings will not waterproof a brick-veneer wall.
3	Same as for Tests 1 and 2.	The wall was coated with asphalt cement. Figure 10 shows the wall after the test.	The wall still leaked in a couple of places. After the bulkhead was removed, no flaws could be observed in the asphalt cement coating in areas where the wall leaked. This implies that great care must be exercised, even if asphalt cement is put on the wall, or water will penetrate into the house. The wall leaked so badly that the closure was not tested for water depths greater than about 15 in.* This type of closure will work, but it is impractical because it takes too much caulking, time, and care to seal it against the wall and floor.

10. The gage layout system is presented in Figure 11.

11. The deflected shape of the wall was measured for each test. The deflections showed that the upper portions of the wall deflected toward the water for low water loadings. Wall 2, which was a double brick wall, deflected considerably less than a single layer brick wall. The deflection curves are not presented in this report; because, besides from a general and relative sense, they do not have significant meaning.

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* A table of factors for converting U. S. customary units of measurements to metric (SI) units is presented on page 4.

Figure 9. Closure made of plywood and 2 x 2's

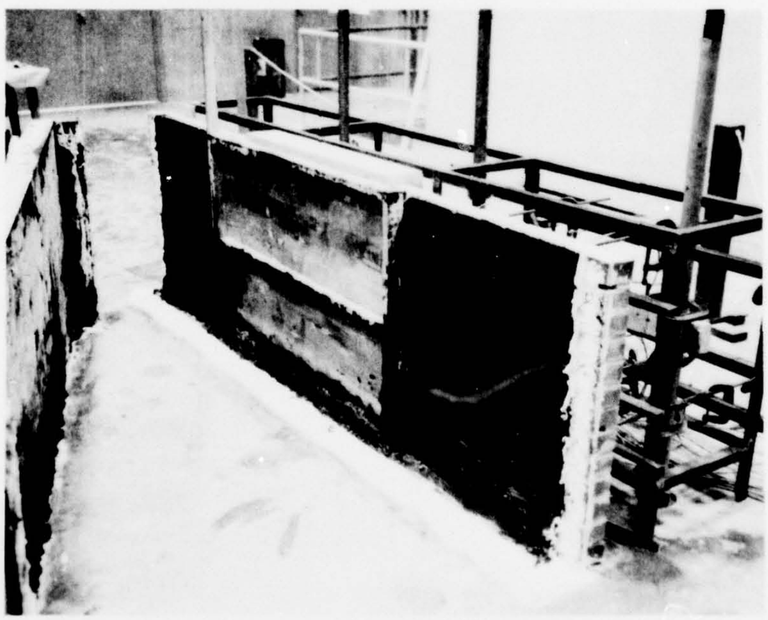


Figure 10. Brick walls coated with asphalt cement

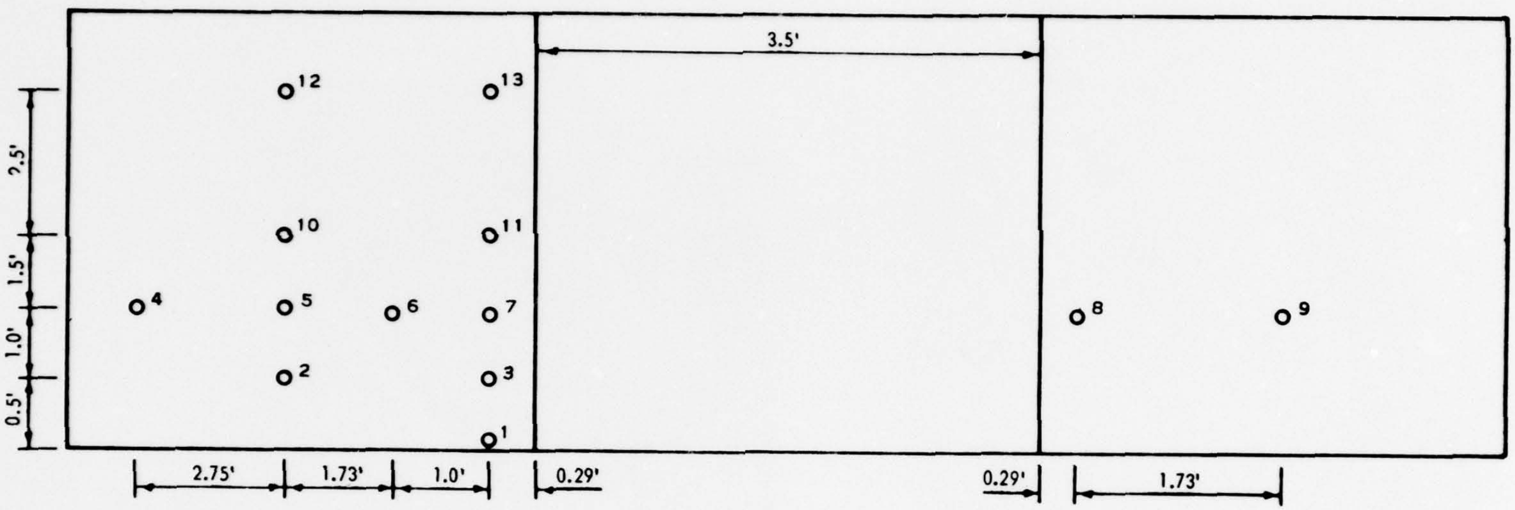


Figure 11. Gage layout

13. The upper part of the wall deflected toward the water for low water depths as had been the case in the prototype tests. This happened because the wall at the location of water pressure deflected away from the loading causing differential lengths in those areas to pull the higher portions of the wall, causing the wall to cup forward toward the water loading.

Wall 2

14. Since it was found very difficult to adequately reduce the flow of water through the brick-veneer wall, it was decided to simulate using a double brick wall with a water barrier between the two layers of brick. The height of the double wall was to be a reasonable distance above the expected flood level. This wall was constructed as follows:

- a. A one-layer brick wall was constructed and coated with asphalt cement. Roofing felt (Figure 12) was embedded in the asphalt cement on one-half of the wall, and polyethylene was embedded in the other (Figure 13). Another layer of asphalt cement was put over the felt and polyethylene to form the water barrier. The barrier was also cupped and stuck to the floor to keep water from penetrating under the wall.
- b. Another layer of brick was constructed in front of the water barrier to protect the barrier and also to conceal it for appearances.
- c. The double wall gives more rigidity and strength causing it to support a greater depth of flood waters.
- d. Channels were attached to the brick sides of the door opening and angles were fixed at the base to hold a piece of plastic-coated plywood as a closure (Figure 14). Two sheets of plywood (Figure 15) were used in order to check the penetration of water to the barrier, along it and out between the two layers of brick at the closure into the space between the two sheets of plywood. In other words, we knew the closure should be on the opposite side of the water barrier from where the water was applied but the second sheet of plywood was placed on the same side of the barrier as the water was applied. The criticalness of the closure location could be checked by how fast the space between the two sheets of plywood filled up with water. The summary of tests on Wall 2 is as follows:

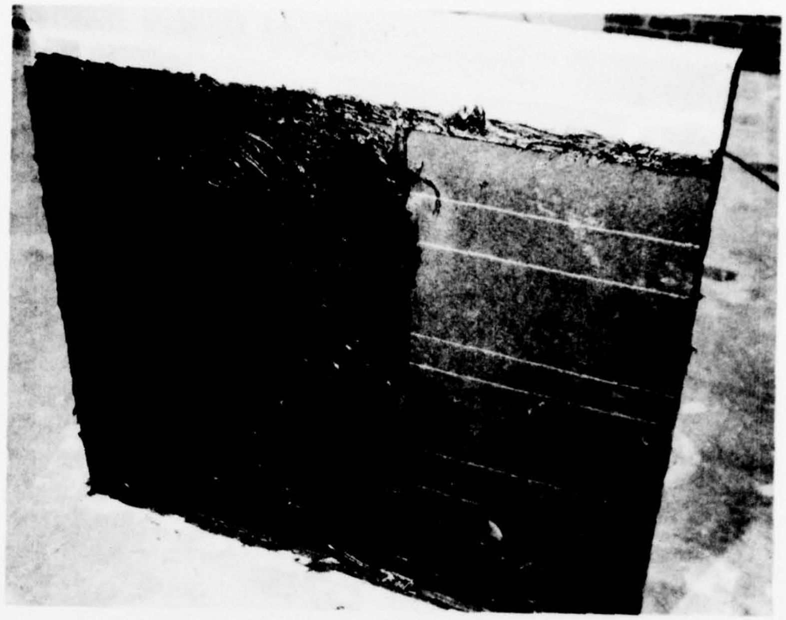


Figure 12. Water barrier composed of asphalt cement, roofing felt, and more asphalt cement

Figure 13. Water barrier composed of asphalt cement, polyethylene, and more asphalt cement.

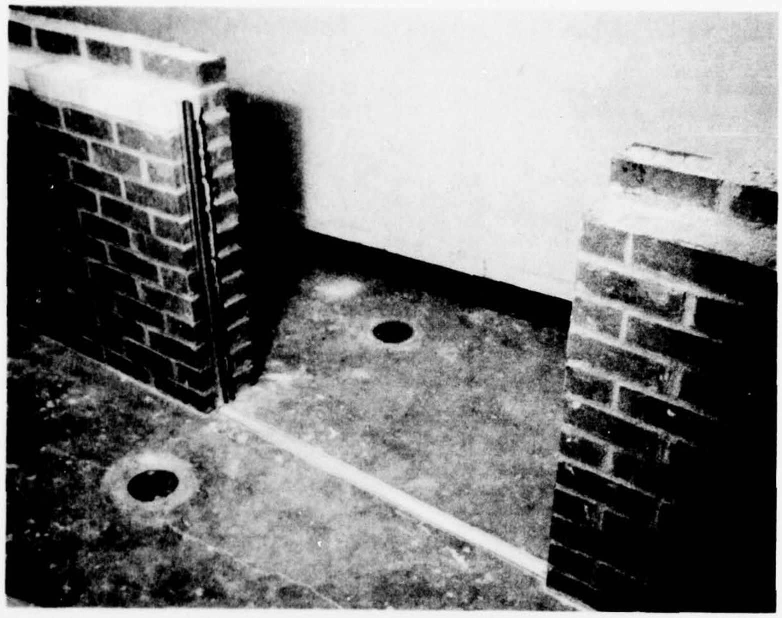


Figure 14. Channels and angles to hold the closure

Figure 15. Two sheets of plywood used to form a closure

Test	Closure	Wall	Test Results
1	Caulking compound was applied to the channels and angles. The plywood was then pushed, with its ends in the channels, down against the angle to form the closure.	The wall was composed of two layers of brick with a waterproof barrier in between as has already been explained.	The closure leaked so badly that the system could not be tested. The water did not go through the wall. Water freely flowed to the barrier, along it, and out the ends of the wall.
2	Same as for Test 1 except that the caulking was applied more heavily to the closure.	Same as for Test 1 except plywood with caulking (Figure 16) was screwed to the outside ends of the wall to stop the water leaks which were coming from along the waterproof barrier and out the ends of the wall.	The closure still leaked. Water did not come through the walls but flowed along the barrier and out of the wall so freely that the test could not be completed.
3	The channels and angles were removed from the closure. Angles were welded to fit tightly against the sides and bottom of the door space. The angles were attached to the brick wall and to the floor of the doorspace using an epoxy resin adhesive. Gasket material was used on the plywood closure and it was bolted to the angles.	Same as for Test 2.	The closure did not leak. Water did not come through the wall. Water still leaked from the outside ends of the walls.
4	Same as for Test 3.	The seals at the outside ends of the walls were tightened after more adhesive was applied.	The closure was a success. The wall was a success.

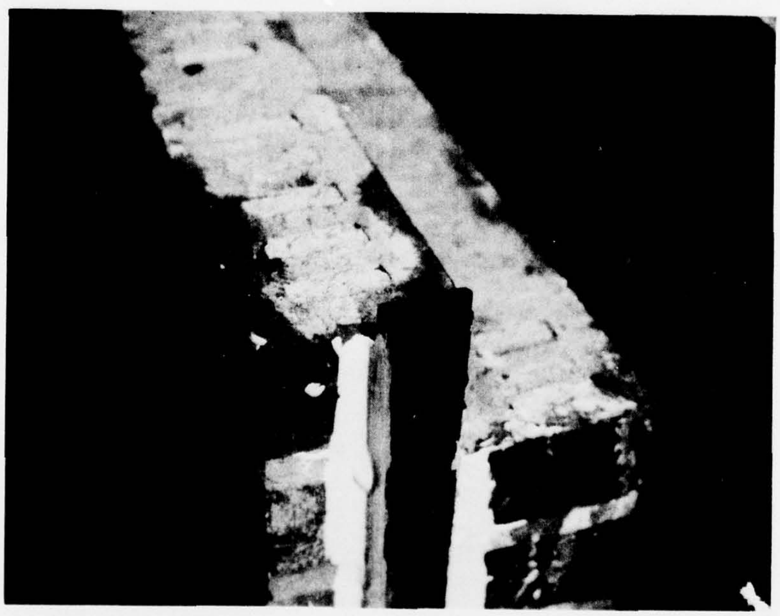


Figure 16. Plywood with caulking was screwed to the end of the brick wall to stop leaks from between the wall layers

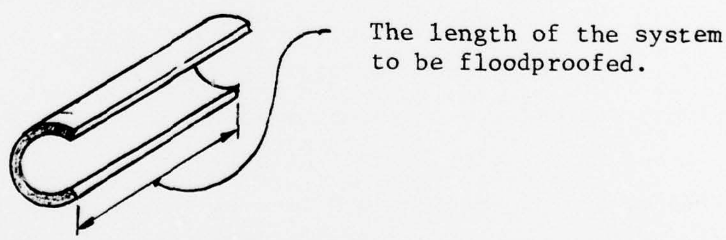
15. For a closure not to leak at its intersection with the sides and bottom of the door space, rubber gasket material, some adhesive, and bolts must be used to tighten and seal its sides and bottom. The two-layer wall was structurally more resistant to water loadings. The wall with the inner seal, as described above, will not leak. Water will freely flow through the first brick layer to the water barrier, along the barrier, and out at the ends of the walls.

Wall 3

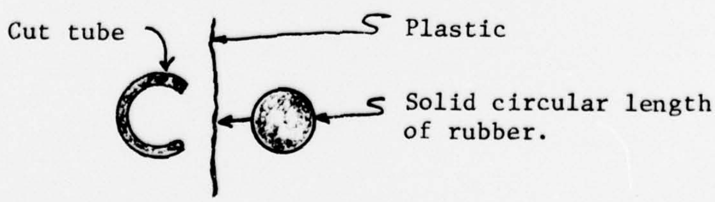
16. A concrete beam was cast at the base of Wall 3 to represent the footing under the brick wall. A tubular seal was used to encase a sheet of plastic at the footing of the wall. The plastic was then pulled up and over the wall and closure. This formed a waterproof barrier over the wall and closure. This system is presented in Figure 17. The closure consisted of a piece of plywood placed against the wall to support the plastic.

17. The tubular seal was constructed as follows:

   a. About one-third of the tube was cut away. The tube was epoxied to the footing with the cut surface turned to the outside.



   b. A solid circular length of rubber was placed against the plastic and snapped into the cut tube.



   This would make a seal at the base of the building.

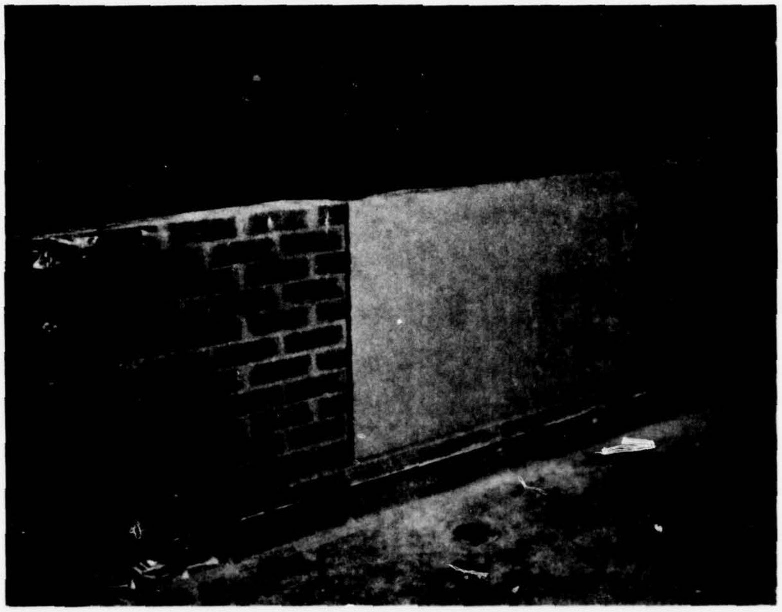


Figure 17. Footing, tubular seal, and plastic waterproofing barrier

18. Only one test was performed, but the system performed well. There was difficulty encountered which caused the test to be stopped, but it had no relation to the waterproofing system itself. Water got under the bottom of the beam and base of the wall causing leakage so bad that further testing would have been useless. A particular advantage to this system is that seals and gaskets for individual openings in the structure are not necessary.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

19. Floodwaters are an expensive problem for the owners of many residential and commercial buildings; therefore, it is important to determine expedient, feasible, and effective ways of floodproofing buildings subject to potential flooding.

20. Important conclusions reached while performing this study are:

- a. The common brick-veneer wall leaks excessively.
- b. The wall can be protected against excessive flow of water through it by using a coating which is thick and has body. This type of coating must be applied with great care, or leaks in the wall will still exist. This solution was not successfully tested in the laboratory experiments. Because of excessive coating material, time, and care, this may not offer a practical solution.
- c. For a closure to be watertight, it must have gasket material at its connection to the side walls and bottom and must be bolted. The connections for the closure at the side walls and floor must be continuous and sealed securely to the walls and floor.
- d. Water will flow freely through a brick wall and along a water barrier in the wall.
- e. Two layers of brick will allow a brick wall to support greater water depths.
- f. A tubular seal and plastic sheet can be used to waterproof a wall and closure.

21. The limited tests run show that solutions can be obtained to the floodproofing problem and that effective procedures can be established which will allow brick-veneer walls to structurally support any reasonable water depth.

22. It is not advisable to develop on paper a system for reducing the flow of water through walls and depend on it without first testing it for performance.

23. A detailed literature review and an imaginative effort should be made to establish a complete description of possible systems. The systems should then be reviewed carefully to determine those which would be most practical and feasible for the homeowner. The systems

should be tested in order of priority until an adequate number have been established as effective. The homeowner can pick the system which best fits his situation and can floodproof his home.

24. Evaluation and structural modification of existing and planned construction for adequacy to resist flood loads should be studied. Findings should be reduced to simple explanations, tables, and charts whereby the homeowner can evaluate and modify his home to be structurally safe after floodproofing measures have been completed.

25. The problem of underseepage and the limitations it places on floodproofing homes should be studied and adequate preventative measures determined. Measures to reduce the underseepage problem to a satisfactory level should be determined.

26. There are many variables which will affect the response of a wall. Some of these are:

- a. wall length
- b. wall height
- c. number and type of openings
- d. impact load
- e. wave loads
- f. vibrations
- g. roof rafter and ceiling joist restraints
- h. inside finishing materials
- i. stud to base plate restraints
- j. wall tie restraints
- k. oscillation between wall ties
- l. boundary effects
- m. material properties
- n. structural modifications

It is too expensive and time consuming to vary these parameters experimentally and determine their effect and the general response of the wall; therefore, it is desirable that analytical solutions and plans for analytical studies be developed. They can be used to make parameter studies, determine the effect of structural modifications, and develop aids for helping the homeowner effectively and economically prepare this home to resist a specific flood load.

27. The above program is an ambitious one, but would facilitate the writing of a homeowners' manual adequate for use by the general public in evaluating their situation and floodproofing their homes.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Pace, Carl E

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